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A Stepwise Fitting Procedure for automated fitting of Ecopath with Ecosim models

Erin Scott^{a,*}, Natalia Serpetti^a, Jeroen Steenbeek^b, Johanna Jacomina Heymans^a

^a Scottish Association for Marine Science, Oban, Argyll, PA37 1QA, UK

^b Ecopath International Initiative Research Association, Barcelona, Spain

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Abstract

The Stepwise Fitting Procedure automates testing of alternative hypotheses used for fitting Ecopath with Ecosim (EwE) models to observation reference data (Mackinson et al. 2009). The calibration of EwE model predictions to observed data is important to evaluate any model that will be used for ecosystem based management. Thus far, the model fitting procedure in EwE has been carried out manually: a repetitive task involving setting >1000 specific individual searches to find the statistically 'best fit' model. The novel fitting procedure automates the manual procedure therefore producing accurate results and lets the modeller concentrate on investigating the 'best fit' model for ecological accuracy.

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Keywords: Stepwise model fitting procedure; Ecopath with Ecosim; Ecological modelling; Model fitting

Code Metadata

Current code version	V1
Permanent link to code/repository used of this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-15-00065
Legal Code License	GNU General Public License
Code versioning system used	svn
Software code languages, tools, and services used	Visual Basic.Net
Compilation requirements, operating environments & dependencies	OS needs to be Microsoft Windows XP service pack 3, Windows Vista, Windows 7, Windows 8.X, or Windows 10 or newer with .NET Framework 4 Full installed. If the computer does not run Microsoft Office 2007 or newer will need to install Microsoft Access 2007 database drivers.
If available Link to developer documentation/manual	https://github.com/ElsevierSoftwareX/SOFTX-D-15-00065
Support email for questions	ewedevteam@gmail.com

1. Motivation and significance

Ecopath with Ecosim (EwE) is an ecological modelling software suite that is freely accessible with over 6000 registered

users from 164 countries [1,2]. It is used to build models of marine and freshwater as well as terrestrial ecosystems. Ecopath describes energy flows through a trophic web of functional groups. Ecosim provides a time-dynamic simulation of the ecosystem, with key initial parameters inherited from the base Ecopath model [1].

The calibration of Ecosim models by fitting model predictions to time series reference data (observations) is important, as it evaluates the assumptions made when parameterising the Ecopath model [3]. The model fitting procedure tests a

* Correspondence to: Computing Science and Mathematics, University of Stirling, Stirling, FK9 4LA, UK.

E-mail addresses: egs@cs.stir.ac.uk (E. Scott), Natalia.Serpetti@sams.ac.uk (N. Serpetti), jeroen.steenbeek@gmail.com (J. Steenbeek), Sheila.Heymans@sams.ac.uk (J.J. Heymans).

Table 1

The eight alternative hypotheses and changing factors parameterised and compared by the Stepwise Fitting Procedure. ✓ and ✗ indicate if a factor is included and not included respectively.

Hypothesis	Fishing data	Trophic effects (Vulnerabilities)	PP anomaly
Baseline	✗	✗	✗
Baseline and trophic effects	✗	✓	✗
Baseline and PP anomaly	✗	✗	✓
Baseline, trophic effects and PP anomaly	✗	✓	✓
Fishing	✓	✗	✗
Fishing and trophic effects	✓	✓	✗
Fishing and PP anomaly	✓	✗	✓
Fishing, trophic effects and PP anomaly	✓	✓	✓

combination of hypotheses, to assess the top-down and bottom-up controls on the time series dynamics. Vulnerability parameters, indicating the strength of the interaction between predators and prey, and/or an anomaly primary production (PP) function that represent an unknown function that can play a bottom-up control on the ecosystem [4]. Vulnerability parameters and a PP function are estimated using an optimisation search routine in Ecosim which reduces the sum of squares difference between the predicted and observed data. The effects of top-down controls (e.g. fishing) and bottom-up controls (e.g. primary productivity) depend on how the various model ecosystem components interact [3].

The Ecosim fitting procedure has previously been a manual process using the ‘fit to time series’ search interface within EwE [1]. This involves setting up individual searches where specific conditions apply, including selecting specific time series to be enabled or disabled (e.g. with and without fishing), thus searching for best fits with and without fishing. It further involves selecting which search to carry out; vulnerability, PP anomaly or both. The number of parameters to be estimated in the search also needs to be set, and a sensitivity search is needed to determine which vulnerability parameters must be estimated. The set-up of one search therefore needs to be repeated depending on the number of parameters that can be estimated and hypotheses being tested. This repetitive task increases the chances of human error. In a large model such as the model of the West Coast of Scotland [5], which contains 48 time series of catch or biomass that can be used to estimate fitting parameters, either through vulnerability, PP anomaly or vulnerability plus PP anomaly searches, the number of searches to be run becomes substantial. The fitting procedure assumes that the 48 time series are independent, but that each data point in the time series are not, thus we can estimate 47 parameters: 2–23 PP spline points (for smoothing the primary production anomaly over the 23 years of the time series) or 47 vulnerabilities, which leads to 1658 possible combinations to be tested. Previously, manual fitting of the West Coast of Scotland model varied only each 5th combination (i.e. 5, 10, 15 vulnerabilities, 5, 10, 15 spline points etc.) in [5] to reduce the repetitive nature of the task. The fitting procedure developed here gives ecosystem modellers the opportunity to test all fitting combinations with accuracy and speed, and thus allows focus on the analyses of results.

2. Software description

The novel Stepwise Fitting Procedure presented here automates the Ecosim model fitting procedure described in [3] and used by [4,5]. As [3] states it is convention and good practice to explore different search strategies for parameterisations that best explain the observation data to find the best-fit model. The automated procedure focuses on the impact of fishing, changes in the predator–prey dynamics (predation vulnerability settings), changes in primary production (PP), and all of the above [3]. A high level view of the stepwise fitting procedure is shown in Fig. 1. Eight alternative hypotheses are parameterised and compared. A more detailed description of the eight types of hypotheses can be found in [5] and are outlined for convenience in Table 1 which presents the factors which are included in each hypothesis.

The fitting procedure determines all the alternative hypotheses that may describe the observation data in equal measure and finds the ‘best-fit’ model. The alternative hypotheses are calculated by the fitting procedure from the maximum number of parameters that can be estimated ($m - 1$) [6]. The maximum number of estimated parameters m is calculated by the procedure from the total number of loaded time series of type: relative biomass, total mortality, catch and average weight [6]. Here we assume that all the time series data are independent but that each data point in the time series are not independent from the other data points in that series. The hypotheses are listed as fitting iterations in the user interface of the stand-alone version (Fig. 2).

The fitting procedure calculates the total number of iterations for each hypothesis by calculating all combinations of number of parameters estimated (K) based on m and/or the maximum number of spline points. For example, if $m = 3$ then for the hypothesis “Baseline and trophic effects” the procedure would calculate 3 iterations where the value of K will be 1, 2 and 3 in each of the iterations. All forcing data including absolute biomass, forced biomass, time forcing data, effort data by gear type, fishing mortality, forced total mortality and forced catch time series are disabled in baseline iterations [6]. There is the option to include and enable absolute biomass time series to the calculation of m and to include these time series in baseline iterations. If a forcing function is applied to the PP in the model, anomaly and vulnerability plus anomaly iteration searches will be calculated and shown in the iteration list of the fitting procedure user interface. The spline point step size can

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